Journal of the Royal Society of Western Australia, Vol. 66, Parts 1 and 2, 1983.

Geological research on Rottnest Island

by P. E. Playford
Geological Survey of Western Australia

Abstract

Rottnest Island forms part of a chain of limestone islands and reefs marking former Quaternary shorelines. It is composed of Pleistocene to Holocene dune limestone (Tamala Limestone), late Pleistocene coral-reef limestone (Rottnest Limestone), mid-Holocene shell beds (Herschell Limestone), and superficial Holocene deposits.

The Rottnest Limestone coral reef grew about 100 000 years ago when sea level was relatively at least 3 m higher than today. Separation of the island from the mainland occurred about 6 500 years ago as sea level rose near the end of the Holocene Flandrian transgression. This was followed by the extinction of most animal and plant species.

The Holocene transgression reached its peak about 2.6 m above present sea level some 5 500 to 5 000 years ago. Two earlier brief still-stands occurred successively about 0.5 m and 1.2 m above present sea level. The final regression to modern sea level may have been of tectonic (rather than eustatic) origin.

A lens of potable groundwater situated west of the salt lakes has been developed to service settlements on the island.

Introduction

The first detailed geological studies on Rottnest Island were carried out by Teichert (1950). His work dealt mainly with the eastern part of the island and the evidence displayed there of Quaternary sea-level changes. Hassell and Kneebone (1960) studied the island as a B.Sc. Honours project at the University of Western Australia, and their work was summarized by Glenister, Hassell, and Kneebone (1959).

Research by the Geological Survey of Western Australia at Rottnest began in 1976 as part of an investigation into the island's groundwater potential (Playford 1976, Playford and Leech 1977). This work further elucidated the Quaternary geology and geological history and succeeded in finding a source of potable groundwater. Since then work by the Geological Survey has continued, and this paper summarizes present knowledge of the geology of the island.

Geomorphology

Rottnest is the largest island in a chain of limestone islands and reefs on the continental shelf opposite Perth. They are composed of dune limestones marking former mainland shorelines which migrated as sea level rose and fell successively during interglacial and glacial periods of the Pleistocene.

Rottnest Island is characterized by alternating limestone headlands and bays with wide sandy beaches backed by Holocene sand dunes. The coast is fringed by shoreline platforms and offshore "reefs" formed by marine planation of Pleistocene dune limestone and encrusted with thin layers of coralline algae and corals. The Pleistocene dune limestone which underlies most of the island is prominently exposed on the headlands; in the interior it is mainly obscured by a veneer of residual or wind-blown sand.

Salt lakes occupy about 10% of the area of the island. They have elongate-ovoid to sub-circular shapes, and are believed to overlie dolines formed by rainwater solution of the limestone and subsequent collapse of cave systems during low sea levels of the Pleistocene. The dolines were subsequently largely filled with Holocene sediments. The prominent "blue holes" of the Houtman Abrolhos appear to have a similar origin (Playford and Leech 1977). Water levels in the lakes rise to about mean sea level in winter and fall more than a metre in summer. Some of the smaller lakes dry out completely at the end of summer, forming a salt crust, while the larger lakes commonly have late-summer salinities exceeding 150 000 mg/L.

Geology

Rottnest Island is composed of Pleistocene to middle Holocene dune limestone (Tamala Limestone), with a thin intercalation of Late Pleistocene coral-reef limestone (Rottnest Limestone), overlain by thin middle Holocene to modern deposits: shell beds (Herschell Limestone), dune sand, beach sand, swamp deposits, and lake deposits. The surface geology is illustrated on Figure 1.

Rock Units

The *Tamala Limestone* is a unit of eolian calcarenite composed of wind-blown shell fragments with variable amounts of quartz sand, and is characterized by large-scale eolian cross-bedding. Over most of the island the formation is mantled by residual quartz sand derived by weathering of weakly lithified sandy limestone.

The Tamala Limestone is known from coastal areas and islands extending from Shark Bay to the south coast, and it ranges from Pleistocene to Holocene in age. At Rottnest the oldest exposed part of the formation probably dates from the Riss Glaciation and the following transgression; the youngest is Holocene, laid down during the Flandrian transgression. The formation contains some prominent soil horizons marking interruptions in dune building. They are underlain by calcrete layers, often associated with abundant fossil root structures (rhizoliths).

Drilling suggests that the Tamala Limestone below Rottnest is about 115 m thick, extending to 70 m

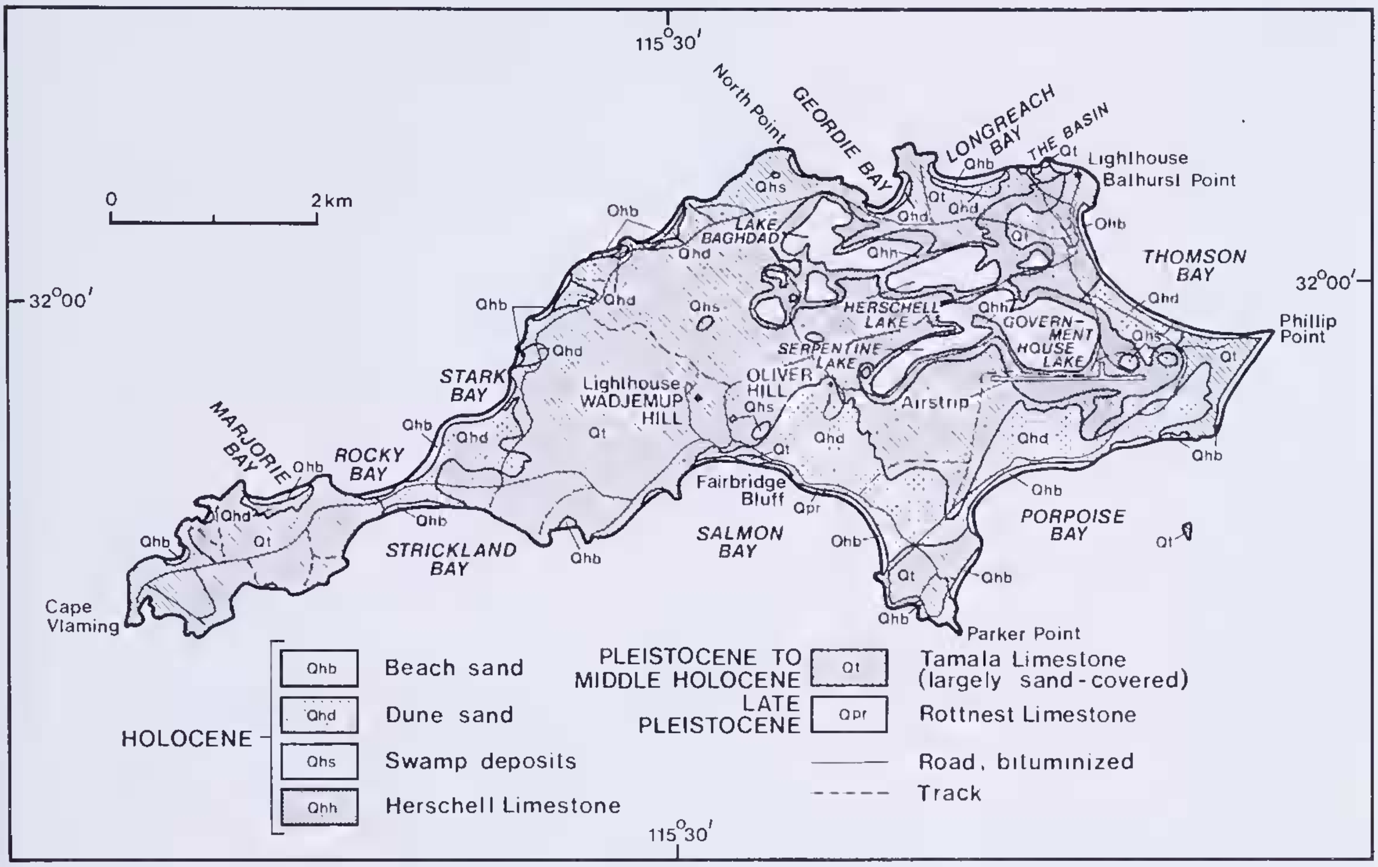

Figure 1.—Geological map of Rottnest Island.

below sea level, where it overlies older Pleistocene or Tertiary sands.

The *Rottnest Limestone* (Fairbridge 1953) is a Late Pleistocene unit of coral-reef limestone and associated shelly (gastropod-rich) limestone exposed at Fairbridge Bluff in Salmon Bay. The formation is overlain and underlain by Tamala Limestone and is believed to represent a marine tongue intercalated in that formation. The total exposed thickness of the Rottnest Limestone is 3 m.

The coral fauna is dominated by branching species of *Acropora*, a genus which today is not known further south than the Houtman Abrolhos, 350 km to the north. Its occurrence in the Rottnest Limestone thus indicates warmer-water conditions when the reef grew than those prevailing in the area at present. Coralline algae *(Lithothamnium)* also made substantial contributions to the reef framework.

The Rottnest Limestone has been dated by uranium-thorium methods as 100 000 ± 20 000 years old (Veeh 1966), and it thus dates from the last Pleistocene interglacial period.

The *Herschell Limestone* is a unit of Holocene shell beds with intercalated lime sand and marl which is exposed around the margins of the Rottnest salt lakes. It overlies and abuts the Tamala Limestone and is overlain by superficial Holocene deposits. The unit is at least 3 m thick, and it is believed to have been deposited in subtidal to intertidal environments.

The fauna of the formation is dominated by many species of bivalves and gastropods (Kendrick 1977). All are living species, but some no longer live in the Rottnest area.

Radiocarbon analysis of shells in the formation gives dates of around 5 500 to 5 000 years (Tamers *et al.* 1964, Deevey *et al.* 1959), with one anomalous date of about 3 800 years (Deevey *et al.* 1959), which is probably too low because of contamination by younger carbonate. Playford and Leech (1977) concluded that the Herschell Limestone was probably deposited about 5 500 to 5 000 years ago, at the peak of the Holocene transgression in this area.

Superficial deposits of Holocene age mantle most of the island. They consist of dune sand, beach sand, swamp deposits, lake deposits, and residual sand (largely derived from the Tamala Limestone).

The swamp deposits were laid down in a series of small fresh- and brackish-water swamps. They consist of thin layers of marl, lime sand, peat, and algal sediments. The palynology of these deposits was studied by Hassell and Kneebone (1960), who showed that pollen from tuart, jarrah, marri, white gum, sheoak, peppermint, banksia, and zamia palm occur at depths of a metre or more below the surface. This shows that the typical tuart-woodland association of the mainland occurred on Rottnest in the past, although none of the species occur there naturally today. Playford and Leech (1977) deduced that this floral association (characteristic of mainland coastal areas opposite Rottnest) probably disappeared soon after Rottnest separated from the mainland. At the peak of the Holocene transgression the land area was much smaller than that of the island today (Fig. 3) and the effects of salt spray (inimical to tuart woodland) were consequently more extensive.

The modern salt-lake deposits consist of algal and evaporitic sediments. In Government House Lake they include columnar algal stromatolites growing in water up to about 3 m deep.

Sea-level changes

The most notable feature of the surface geology of Rottnest Island is the excellent evidence there of Quaternary sea-level changes. This is in the form of (a) elevated marine deposits, (b) elevated shoreline platforms and notches, and (c) subaerial features which now extend below sea level.

The Department of Lands and Surveys has recently carried out levelling at Rottnest on behalf of the Geological Survey in order to better relate the various elevated features to their present-day equivalents. Although further levelling is desirable, some preliminary amendments are made in this paper to the approximate elevations assigned by Playford and Leech (1977) to the various emerged features.

The levels of modern shoreline platforms were determined at three localities adjoining the eastern half of the island; these are –0.402 m at The Basin –0.428 m at Fairbridge Bluff, and –0.480 at Thomson Bay (near the hotel). They average about 0.44 m below mean sea level (A.H.D.), which is 0.1 m below mean low water level, and would be exposed about 1% of the time each year (D. F. Wallace, pers. comm., 1982). Elevated shoreline platforms and associated notches, and the top of the fossil coral reef, have been related to this level in order to deduce the amount of emergence that has occurred.

Elevated marine deposits: The fossil coral reef of the Rottnest Limestone extends to 3.02 m above the adjoining shoreline platform. Consequently it is concluded that sea level relative to Rottnest during the last interglacial was at least this amount higher than it is today. However, this is a minimum figure, as the top of the coral reef could have grown in water several metres deep.

The highest marine shell beds of the mid-Holocene Herschell Limestone extend to about 2.15 m above mean sea-level or 2.6 m above the modern shoreline platforms. This is the same level as the highest of the emerged shoreline platforms, and both apparently formed at about the same time, some 5 500 to 5 000 years ago.

Elevated platforms and notches: Three levels of elevated shoreline platforms and notches are recognibed at Rottnest Island: an upper level at about 2.6 m, an intermediate level at about 1.3 m, and a lower level at about 0.5 m above the modern shoreline platforms (Fig. 2). These are the "3 m, 1.5 m, and 0.7 m" levels of Playford and Leech (1977).

The upper (2.6 m) level is visible at many places around the coast, and especially around the salt lakes. The intermediate (1.3 m) and lower (0.5 m) levels are best preserved around the lakes, in the form of notches with weakly developed narrow platforms (Playford and Leech 1977, Figs. 15-17). The intermediate and lower levels are rarely preserved around

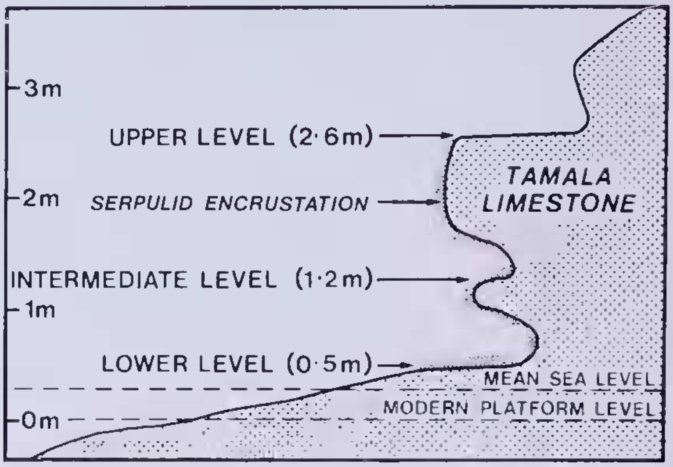

Figure 2.—Diagram illustrating elevated shoreline platforms and notches around the Rottnest salt lakes. The elevations of these features are related to the average elevation (0.44 m below mean sea level) of modern shoreline platforms around the island.

the coast of the island, as there they are subject to modern wave attack.

At many localities a layer of serpulid worm tubes is discontinuously preserved encrusting the two lower notches and platforms, and extending up to the upper-level platform (Fig. 2). The limestone on which the serpulids grew is commonly intensely bored by marine organisms. Some pockets of bivalves and gastropods (species also found in the Herschell Limestone) are associated with the serpulid layer, and there are also some encrustations of bryozoans and small solitary corals. These organisms grew under subaqueous marine conditions and once formed an essentially continuous crust over the surface below the upper-level platform. From this it is clear that the two lower notches and their associated platforms were already in existence when the transgression reached the upper (2.6 m) level. Each of the three levels is believed to represent a still-stand of no more than a few hundred years as relative sea level rose through three steps to its final peak about 5 500 to 5 000 years ago. The regression following this peak must have been abrupt; otherwise the relatively fragile serpulid crust would have been removed by marine erosion.

Subaerial features extending below sea level: Lithified dune limestone of the Tamala Limestone extends below sea level around the coast of Rottnest, and may reach depths of 70 m or more. Most of the formation is thought to have accumulated when sea level was considerahly lower that it is today.

At several localities around the coast solution pipes in the Tamala and Rottnest Limestones can be seen extending below sea level, testifying to sea levels lower than at present when they formed. As previously mentioned, the salt lakes probably overlie major dolines formed by rainwater solution and collapse during the low sea-level stands of the glacial periods.

Origin of sea-level changes

The major changes of sea level affecting the Swan Coastal Plain and adjoining continental shelf during the Pleistocene resulted from eustatism associated with waxing and waning of the continental ice sheets (see discussions in Playford *et al.* 1976 and Playford and Leech 1977). However it is doubtful that the Holocene "high sea levels" evidenced at Rottnest and elsewhere along the Western Australian coast were truly eustatic (i.e. world-wide events), as had been postulated by Teichert (1950), Fairbridge (1958 and 1961), and Hassell and Kneebone (1960).

As pointed out earlier, there was apparently an abrupt fall in sea level at the close of the still-stand evidenced by the upper-level platform. This prompted Playford and Leech (1977) to suggest the possibility that it had a tectonic origin.

However, it still remains to be shown whether this relative fall in sea level during the mid Holocene was of regional or local extent. If it was regional, did it result from world-wide eustatism, epeirogenic uplift, global changes in the geoid, or some other cause? If the relative fall in sea level was of local extent, did it result from movement along a fault on or adjoining the continental shelf, possibly triggered by rapid loading of water during the Flandrian transgression, or was it associated with movement along the Darling Fault? The answers to these questions must await further precise work to correlate emerged platforms and other features at Rottnest with similar features in Western Australia and elsewhere in the world.

Quaternary geological history

The foundations of Rottnest Island may have been originally localized by a sand shoal, perhaps associated with an uplifted area in underlying Tertiary rocks. Calcareous sand dunes accumulated in the area during the Pleistocene to form the Tamala Limestone. This formation had a long history of dune building, soil development, and karstification during successive glacial and interglacial periods of the Pleistocene. The oldest dune limestones exposed on the island may date from the Riss Glaciation and the ensuing transgression, but older Pleistocene parts no doubt occur in the subsurface.

During the Riss-Wurm interglacial a coral reef grew on the dune ridge of Tamala Limestone. Sea level fell progressively during the Wurm glaciation, reaching its lowest level of about 130 m below its present level some 18 000 years ago. The coastline was then about 12 km west of Rottnest (Fig. 3), and the old dune and reef limestones stood as a

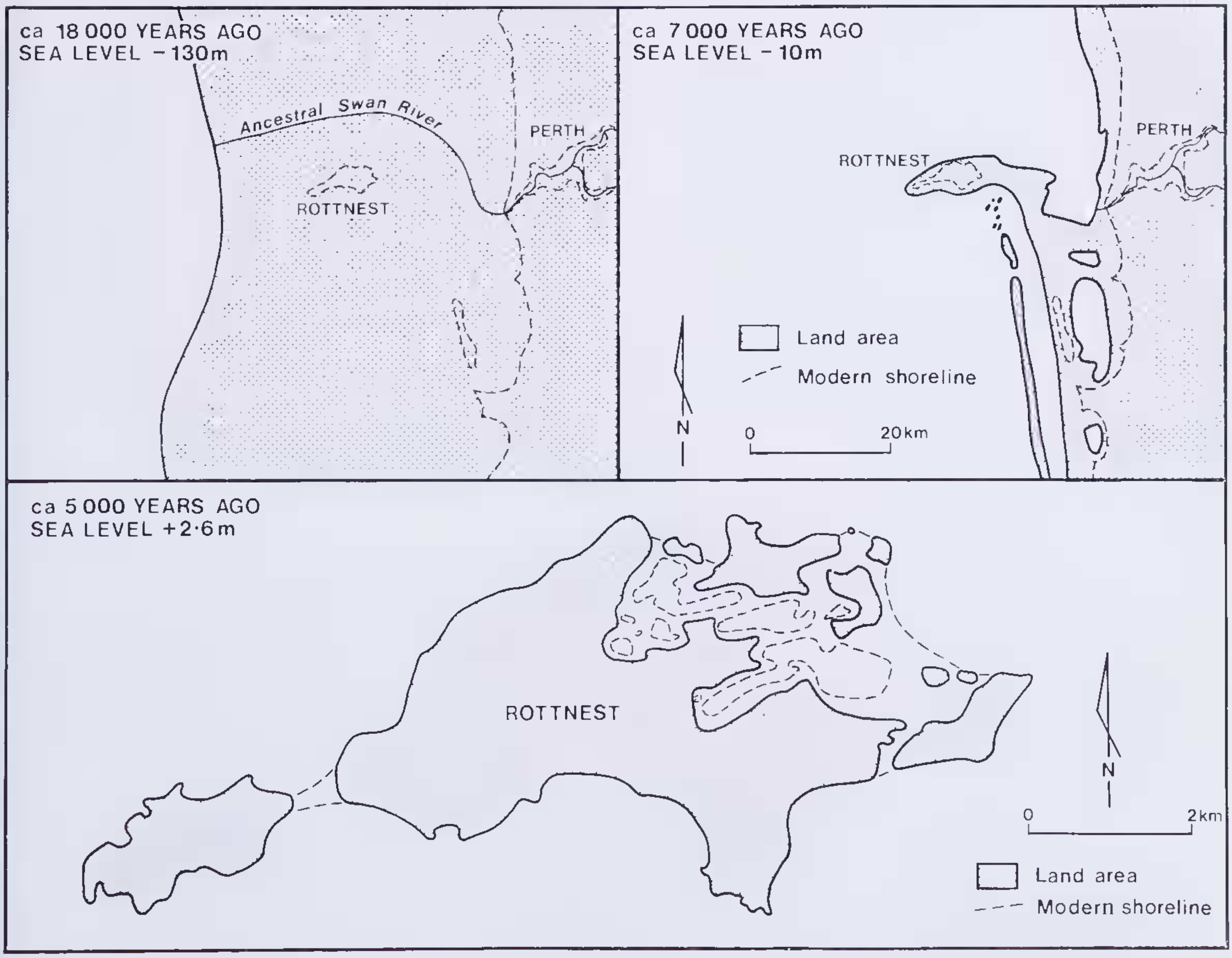

Figure 3.—Palaeogeographic maps illustrating shoreline changes in the Rottnest-Perth area during the late Pleistocene and Holocene.

conspicuous "mountain" high above the surrounding plain. The ancestral Swan River then flowed out to sea northwest of Rottnest, where it joined a submarine canyon (the Perth Canyon) incised into the continental slope. Strong karst solution proceeded in the limestones, with the formation of the large dolines that were afterwards to localize the modern salt lakes.

Sea level rose rapidly during the Holocene Flandrian transgression. Dune sands of the younger Tamala Limestone accumulated on the Rottnest platform as part of a belt extending through the present Carnac, Garden, and Penguin Islands. As the sea rose towards its present level, Rottnest remained in connection with the mainland along this belt of dunes (Fig. 3). The island probably separated about 6 500 years ago. Major changes in the land flora and fauna of the island followed this separation; only a few of the original plants and animals survived to the present day.

The maximum submergence at Rottnest, to about 2.6 m above present sea level, probably occurred some 5 500 to 5 000 years ago. The area of the present salt lakes then formed arms of the sea between more than 10 separate islands (Fig. 3). Prolific molluscan faunas lived in the warm shallow waters between these islands, and their close-packed shells now form much of the Herschell Limestone.

There were two brief intervals of still-stand, totalling no more than a few hundred years, at about 0.5 m and 1.2 m above present sea level, as the sea rose to its peak (2.6 m) level. Notches and narrow shoreline platforms were eroded at each of those levels.

There was an abrupt fall in sea level, or the Rottnest area was suddenly uplifted, about 5 000 years ago, when the sea attained its present level relative to the island. The area of the present salt lakes remained in connection with the sea for some time, but it was eventually cut off by the accumulation of beach ridges and sand dunes. Superficial deposits continued to accumulate after that time, but there have probably been no major changes in the configuration of the island for the past 2 000 or 3 000 years.

Hydrogeology

The supply of domestic water in sufficient quantities and at reasonable cost was a major problem at Rottnest for more than 60 years. After World War II most drinking water came from sealed catchment areas and (1961 to 1976) by barge from the mainland. However, when a decision was made in 1975 to build a second settlement at Longreach and Geordie Bays, it was clear that some new water source would have to be found, either

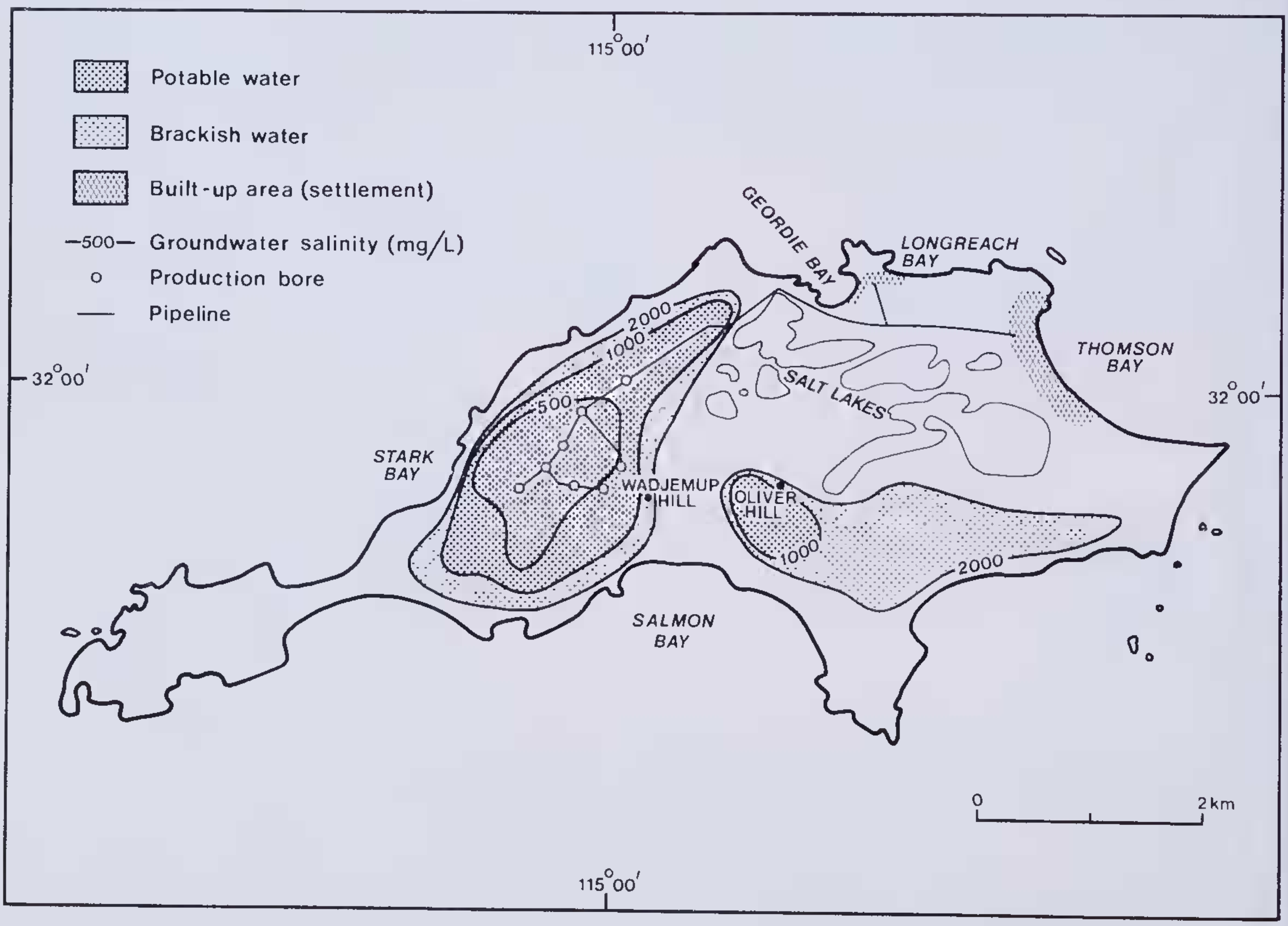

Figure 4.—Map showing the locations of fresh and brackish groundwater lenses below Rottnest Island.